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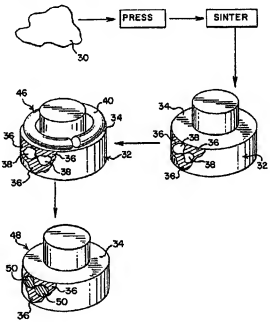
(54) METHODE DE FABRICATION DE PRODUITS DE METAL FERREUX INFILTRE DE CUIVRE
(54) METHOD OF MAKING COPPER INFILTRATED FERROUS METAL PRODUCTS

(57)

A method of making a relatively small infiltrated ferrous metal product is disclosed. A ferrous metal powder is formed and sintered into a porous product weighing less than 5 ounces. The ferrous metal powder product has a contact surface. A wire or sheet metal infiltrant pre-form is provided. The pre-form is made of a copper-based alloy. The alloy contains elements that reduce the likelihood of erosion of iron in the porous compact. Preferably, the infiltrant pre-form material includes copper and at least about 2.5% iron be weight. A typical pre-form for making this size of product will weigh about 1/2 ounce. The shaped pre-form is placed on the contact surface of the porous metal product. The combination of the infiltrant pre-form and the porous ferrous metal product is heated in a furnace so that at least some of the metal in the infiltrant pre-form infiltrates into the porous metal product to form the infiltrated ferrous metal product. Use of the wire or sheet metal infiltrant pre-form instead of a powder metal infiltrant compact lessens breakage in the snaking of small parts.



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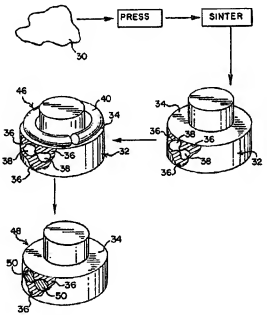
(54) Titre : METHODE DE FABRICATION DE PRODUITS DE METAL FERREUX INFILTRE DE CUIVRE
(54) Title: METHOD OF MAKING COPPER INFILTRATED FERROUS METAL PRODUCTS



(57) Abrégé/Abstract:
A method of making a relatively small infiltrated ferrous metal product is disclosed. A ferrous metal powder is formed and sintered into a porous product weighing less than 5 ounces. The ferrous metal powder product has a contact surface. A wire or sheet metal infiltrant pre-form is provided. The pre-form is made of a copper-based alloy. The alloy contains elements that reduce the likelihood of erosion of iron in the porous compact. Preferably, the infiltrant pre-form material includes copper and at least about 2.5% iron be weight. A typical pre-form for making this size of product will weigh about 1/2 ounce. The shaped pre-form is placed on the contact surface of the porous metal product. The combination of the infiltrant pre-form and the porous ferrous metal product is heated in a furnace so that at least some of the metal in the infiltrant pre-form infiltrates into the porous metal product to form the infiltrated ferrous metal product. Use of the wire or sheet metal infiltrant pre-form instead of a powder metal infiltrant compact lessens breakage in the snaking of small parts.

ABSTRACT

A method of making a relatively small infiltrated ferrous metal product is disclosed. A ferrous metal powder is formed and sintered into a porous product weighing less than 5 ounces. The ferrous metal powder product has a contact surface. A wire or sheet metal infiltrant pre-form is provided. The pre-form is made of a copper-based alloy. The alloy contains elements that reduce the likelihood of erosion of iron in the porous compact. Preferably, the infiltrant pre-form material includes copper and at least about 2.5% iron be weight. A typical pre-form for making this size of product will weigh about ½ ounce. The shaped pre-form is placed on the contact surface of the porous metal product. The combination of the infiltrant pre-form and the porous ferrous metal product is heated in a furnace so that at least some of the metal in the infiltrant pre-form infiltrates into the porous metal product to form the infiltrated ferrous metal product. Use of the wire or sheet metal infiltrant pre-form instead of a powder metal infiltrant compact lessens breakage in the making of small parts.

METHOD OF MAKING COPPER INFILTRATED FERROUS METAL PRODUCTS

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to the manufacture of powder metal products, and more particularly, to a method of making copper infiltrated ferrous metal products.

2. Description of the Prior Art.

It is known to produce metal products by compacting metal powder into a green powder metal compact and then heating the green powder metal compact to sinter the metal particles to produce the metal product. Due to inherent limitations in the manufacturing process, the densities of the metal products typically are below theoretical density; in other words, the green powder compacts and the metal products are typically porous.

The properties of such porous metal products are commonly improved through a technique known as infiltration. In infiltration, the open pore structure of the sintered powder metal product is infiltrated by another metal having a lower melting temperature. This second metal is commonly referred to as an infiltrant.

A typical prior art infiltration process is illustrated schematically in FIG. 1. As there shown, a mass of powdered metal 10 is pressed and sintered to form a sintered porous powder metal product 12. The sintered porous metal product 12 has a contact surface 14, and an interior with pores, shown enlarged and schematically at 16, with the sintered metal shown in cross-hatch at 17. An infiltrant is provided in the form of a green powder metal compact 18. This infiltrant compact is made from powder metal in a typical pressing operation. The green infiltrant compact 18 is placed on the contact surface 14 of the sintered powder metal product 12. The combination is then placed in a furnace at a temperature high enough to melt the metal in the green powder metal infiltrant 18 but lower than the melting temperature of the metal in the sintered powder metal product 12. The metal of the infiltrant 18 melts, and the liquid infiltrant metal flows into the pores of the metal product 12 through capillary action. After the process is complete, the pores 16 are theoretically filled with the metal infiltrant, which solidifies. The infiltrated metal product is shown at 20 with its

pores filled with solid metal infiltrant; the sintered metal is shown at 17 in the cross-hatch angled upward toward the right, and the solid metal infiltrant is shown at 22 in the cross-hatch angled upward toward the left.

Typical infiltrants are metal or metal alloy powders that have been formed into a green compact shape to mate generally with the shape of the contact surface of the metal product to be infiltrated. Copper or copper based alloys have commonly been used as infiltrants for ferrous powder metal product.

One problem with the infiltration technique is known in the powder metallurgy art as erosion. In erosion, some of the metal of the powder metal product or compact at or near the contact surface with the infiltrant compact dissolves in the infiltrant. With such erosion, the dimensions of the metal product may change during infiltration. If the dimensional change is great enough, the infiltrated product may need to be subjected to another manufacturing step, such as sizing, to reach final design dimensions. With the increased density of the infiltrated product after infiltration, it may be difficult to use a pressing step to size the infiltrated product. Machining to final dimensions is an expensive alternative.

Another problem with the infiltration technique relates to the handling of the green infiltrant compacts. Particularly for small parts, the green infiltrant compact is commonly of small size. The small size green infiltrant compacts are more delicate and more difficult to handle: movement of the small green infiltrant compacts in a production operation results in breakage of some of the compacts. The metal powder in the broken compacts is generally not reusable, so this breakage can add significantly to the cost of producing the finished infiltrated metal products.

SUMMARY OF THE INVENTION

The present invention is directed to increasing efficiency in the manufacture of infiltrated powder metal products.

In one aspect, the present invention provides a method of making an infiltrated ferrous metal product. The method comprises the acts of providing a ferrous metal powder and forming the ferrous metal powder into a porous ferrous metal product having a contact surface. An infiltrant pre-form is provided. The infiltrant pre-form is selected from the group consisting of metal wire material and sheet metal material. The infiltrant pre-form is placed on the porous ferrous metal

powder product contact surface. The combination of the infiltrant pre-form and the porous ferrous metal product is heated so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal product to form the infiltrated ferrous metal product.

In another aspect, the present invention provides a method of making an infiltrated ferrous metal compact. A ferrous metal powder is formed into a porous ferrous metal product having a contact surface. A metal wire infiltrant pre-form is provided. The infiltrant pre-form comprises copper and at least about 2.5% iron by weight. The metal wire infiltrant pre-form is placed on the porous ferrous metal powder product contact surface. The combination of the infiltrant pre-form and the porous ferrous metal product is heated so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal product to form the infiltrated ferrous metal product.

In another aspect, the present invention provides a method of making an infiltrated ferrous metal compact weighing less than 5 ounces. The method comprises the acts of providing a ferrous metal powder and forming the ferrous metal powder into a porous ferrous metal product having a contact surface and weighing less than 5 ounces. An infiltrant pre-form is provided, the infiltrant pre-form is made of a material selected from the group consisting of metal wire material and sheet metal material. The infiltrant pre-form weighs less than about ½ ounce. The infiltrant pre-form is placed on the porous ferrous metal powder product contact surface. Then, the combination of the infiltrant pre-form and the porous ferrous metal product is heated so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal powder product to form the infiltrated ferrous metal product.

In another aspect, the present invention provides a method of making an infiltrated ferrous metal compact weighing less than 5 ounces. The method comprises the acts of providing a ferrous metal powder and forming the ferrous metal powder into a porous ferrous metal product having a contact surface and weighing less than 5 ounces. The method further includes providing a metal wire infiltrant pre-form comprising copper and about 2.5% iron by weight. The metal wire infiltrant pre-form weighs less than about ½ ounce, and is shaped to be supportable on the porous ferrous metal powder contact surface. The infiltrant pre-form is placed on the porous ferrous metal powder product contact surface. The combination of the infiltrant pre-form and the porous ferrous metal product is heated so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal product to form the infiltrated ferrous metal product.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, like numbers have been used for like parts and:

FIG. 1 is a schematic drawing showing a prior art infiltration process, with the porous ferrous metal powder product, green infiltrant compact and infiltrated ferrous metal product shown schematically in a perspective view, and with portions of the porous ferrous metal powder product and the infiltrated ferrous metal product shown schematically in cross-section;

FIG. 2 is a schematic drawing showing the infiltration process of the present invention, with the porous ferrous metal powder product, infiltrant pre-form and infiltrated ferrous metal product shown schematically in a perspective view, with portions of the porous ferrous metal powder product and the infiltrated ferrous metal product shown schematically in cross-section;

FIG. 3 is a perspective view of an alternate infiltrant pre-form on a porous ferrous metal powder product; and

FIG. 4 is an elevation of a third embodiment of an infiltrant pre-form.

DETAILED DESCRIPTION

The present invention provides an efficient method of making infiltrated ferrous metal products. A schematic illustration of the process of the present invention is shown in FIG. 2. As there shown, a ferrous metal powder 30 is provided. Commercially available metal powders may be used, such as, for example Ancorsteel 1000, available from Hoeganaes Corp., Cinnaminson, NJ. The ferrous metal powder 30 may then be pressed to produce a ferrous metal compact. The ferrous metal compact may then be sintered in a furnace to form a porous ferrous metal product, shown at 32 in FIG. 2. The compaction and sintering steps may employ standard techniques, and it is expected that techniques that are developed in the future may also be used.

If the porous ferrous metal product 32 is to be infiltrated, it will typically have a contact surface. The contact surface may comprise an annular surface of the metal product, as shown at 34 in FIG. 2. The contact surface 34 is provided as a surface for supporting the infiltrant pre-form, and should have a shape that will enable it to perform that function. Since there is a possibility of some erosion of this contact surface, it should be designed as part of an area of the metal product where dimensional control is less critical.

To illustrate the process of the present invention, a portion of each porous ferrous metal product 32 is shown schematically in cross-section in FIG. 2. As there shown, the porous ferrous metal product comprises areas of sintered metal shown at 36, and pores shown at 38. It should be understood that these features are enlarged and shown schematically in FIGS. 2-3 for purposes of illustration.

In the present invention, instead of a green powder metal compact as in the prior art, the infiltrant is provided in the form of a solid metal alloy pre-form. The infiltrant pre-form may comprise a metal wire material shaped to mate generally with the shape of the contact surface of the metal product, as shown 40 at in FIG. 2. Alternatively, the infiltrant pre-form may comprise a sheet metal material cut into a shape to mate with the shape of the contact surface of the metal product, as shown at 42 in FIG. 3. Most typically, the shape of the infiltrant pre-form 40, 42 will comprise an annulus, although it may be desirable to form the solid metal material into a helical shape, for example, as shown at 44 in FIG. 4, if the metal product is of larger size requiring a greater quantity of infiltrant. If annular, the ends of the infiltrant pre-form 40, 42 need not meet; there may be some small space between the ends, or the ends may overlap slightly. Other shapes of infiltrant pre-forms may be used as well, and the invention is not limited to any particular shape unless the claims expressly so require.

The infiltrant pre-form is preferably made of a copper alloy material that includes more than 0.8% iron by weight. A particularly useful alloy includes copper and iron, the iron comprising about 2.5% by weight of the alloy. This solid metal alloy material is a commercially available one. It is designated alloy C19400. The higher iron content of this alloy is desirable in reducing erosion of the porous ferrous metal product during infiltration.

Because of the higher iron content, this copper alloy is not typically available in wire form. The increased iron content affects the formability of the alloy into wire and into a usable pre-form. Accordingly, it may be desirable to obtain the copper alloy material in sheet form, and to cut the pre-form from the sheet, like the embodiment shown at 42 in FIG. 3. A suitable sheet material for copper alloy C19200 is available from ABC Metals, Inc., of Logansport, IN in thicknesses of about 0.064 inch. However, a wire form of copper alloy C19400 is commercially available from Lewis Spring, Niles IL, and is suitable for forming the infiltrant pre-form shape shown at 40 is FIG. 2, as well as the pre-form shape shown at 44 in FIG. 4. Typical wire diameters for the pre-forms will be

on the order of about 0.08 inch. It should be understood that the present invention is not limited to this particular alloy or to this particular suppliers. It should be understood that different alloys may be chosen, with constituent elements selected to reduce the solubility of the iron in the copper alloy. For example, an alloy containing manganese may also be possible. Generally, the alloy should include an element that limits the solubility of iron during the infiltration process, in an amount that allows for efficient forming of a wire form of the alloy or that allows for efficient cutting of a sheet metal form of the alloy to produce the desired pre-form shape. The amount and identity of the element used to limit solubility of iron may be selected based on known criteria, such as the location of the contact surface, and the degree of dimensional control needed for the contact surface, for example.

The characteristics of the material for the infiltrant pre-form may generally be selected with cost-effective processing in mind. For example, the thickness or diameter of the material should be such that allows the raw material to be economically shaped into the desired pre-form shape, such as the annulus or helix shown at 40 and 44 in FIGS. 2 and 4, and for the sheet product, for the desired shape to be cut from the sheet metal. Other alloying elements that improve the formability of the solid metal could be used, although they preferably do not increase the solubility of iron in the infiltrant.

The infiltrated ferrous metal product is produced by placing the infiltrant pre-form 40, 42 or 44 on the contact surface 34 of the porous ferrous metal product 32, as shown in FIG. 2. The combination of the infiltrant pre-form and the porous ferrous metal product, shown at 46 in FIG. 2, is then heated in a furnace in the usual manner. At least some of the metal in the infiltrant pre-form 40, 42 or 44 will infiltrate into the pores 38 of the ferrous porous metal product 32 and solidify to form the infiltrated ferrous metal product. The infiltrated ferrous metal product is shown at 48 in FIG. 2, with the solid infiltrant shown at 50, in what previously were the pores 38.

With the level of iron content of the pre-form 40, 42, or 44, erosion of the contact surface 34 of the porous ferrous metal product 32 during infiltration should be reduced. With the use of a solid metal pre-form 40, 42, or 44 instead of a green powder compact 18 as the carrier for the infiltrant, breakage during handling of the infiltrant pre-form should be minimized.

The method of the present invention is expected to be particularly useful in the production of relatively small products. For mid-size to large porous ferrous metal products, it is expected that

use of the standard prior art process will be most cost-effective; the copper infiltrant can be provided in the form of a green powder metal compact that is formed using traditional powder metal processes. Powder metal mixes with relatively high concentrations of iron are commercially available, and standard practices may be used to minimize erosion of critical areas of the product.

However, for producing smaller infiltrated ferrous metal products, such as products up to about 4 ounces in total weight (or less than about 5 ounces), the method of the present invention should be more cost effective. Generally, in the infiltrated product, the amount of copper will be about 10% by weight. A green powder metal copper infiltrant compact weighing ½ ounce or less is difficult to handle in a manufacturing operation without incurring breakage. Since a green powder metal infiltrant compact, once broken, cannot be reused, breakage leads to increased costs. However, with a solid metal form of infiltrant, either in the form of a wire or sheet metal pre-form, breakage of the infiltrant pre-form will generally not be an issue even if the pre-form weighs less than ½ ounce. Thus, for the production of smaller infiltrated ferrous metal products, the method of the present invention should thus be more cost effective than the traditional prior art method.

An example of a small infiltrated ferrous metal product that may be advantageously made using the method of the present invention is a shoe for a diesel engine fuel pump. The product so made should meet industry standards, such as standard MPIF FX 1008.

It should be understood that standard commercial practices may be employed with the present invention. For example, prior art methods for determining the preferred area of contact between a green infiltrant compact and the contact surface of the porous metal product may be used in determining the preferred area of contact between an infiltrant pre-form of wire of cut sheet metal and the contact surface of the porous metal product.

While only a specific embodiment of the invention has been described and shown, it is apparent that various alternatives and modifications can be made thereto. Those skilled in the art will recognize that certain modifications can be made in this illustrative embodiment. It is, therefore, the intention in the appended claims to cover all such modifications and alternatives as may fall within the true scope of the invention.

CLAIMS

We claim:

1. A method of making an infiltrated ferrous metal product, the method comprising the acts of:

providing a ferrous metal powder;

forming the ferrous metal powder into a porous ferrous metal product having a contact surface;

providing an infiltrant pre-form selected from the group consisting of metal wire material and sheet metal material;

placing the infiltrant pre-form on the porous ferrous metal powder product contact surface; and

heating the combination of the infiltrant pre-form and the porous ferrous metal product so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal product to form the infiltrated ferrous metal product.

2. The method of claim 1 wherein the infiltrant pre-form is selected from the group consisting of:

metal wire material comprising a copper alloy having more than 0.8% iron; and

sheet metal material comprising a copper alloy having more than 0.8% iron.

3. The method of claim 2 wherein the infiltrant pre-form is selected from the group consisting of:

metal wire material comprising a copper alloy having about 2.5% iron; and

sheet metal material comprising a copper alloy having about 2.5% iron.

4. The method of claim 1 wherein the infiltrant pre-form has an annular shape.

5. The method of claim 1 wherein the infiltrant pre-form has a helical shape.

6. The method of claim 1 wherein the infiltrated ferrous metal product weighs less than 5 ounces.

7. The method of claim 1 wherein the infiltrant pre-form weighs less than ½ ounce.

8. A method of making an infiltrated ferrous metal compact, the method comprising the acts of:

providing a ferrous metal powder;

forming the ferrous metal powder into a porous ferrous metal product having a contact surface;

providing a metal wire infiltrant pre-form comprising copper and at least about 2.5% iron by weight;

placing the metal wire infiltrant pre-form on the porous ferrous metal powder product contact surface; and

heating the combination of the infiltrant pre-form and the porous ferrous metal product so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal product to form the infiltrated ferrous metal product.

9. The method of claim 8 wherein the infiltrant wire pre-form has an annular shape.

10. The method of claim 8 wherein the infiltrant wire pre-form has a helical shape.

11. The method of claim 8 wherein the infiltrant wire pre-form weighs less than ½ ounce.

12. The method of claim 8 wherein the infiltrated ferrous metal product weighs less than 5 ounces.

13. A method of making an infiltrated ferrous metal compact weighing less than 5 ounces, the method comprising the acts of:

providing a ferrous metal powder;

forming the ferrous metal powder into a porous ferrous metal product having a contact surface and weighing less than 5 ounces;

providing an infiltrant pre-form made of a material selected from the group consisting of metal wire material and sheet metal material, the infiltrant pre-form weighing less than about ½ ounce;

placing the infiltrant pre-form on the porous ferrous metal powder product contact surface; and

heating the combination of the infiltrant pre-form and the porous ferrous metal product so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal powder product to form the infiltrated ferrous metal product.

14. The method of claim 13 wherein the infiltrant pre-form has an annular shape.

15. The method of claim 13 wherein the infiltrant pre-form has a helical shape.

16. The method of claim 13 wherein the infiltrant pre-form is selected from the group consisting of:

metal wire material comprising a copper alloy having more than 0.8% iron; and
sheet metal material comprising a copper alloy having more than 0.8% iron.

17. The method of claim 16 wherein the infiltrant pre-form is selected from the group consisting of:

metal wire material comprising a copper alloy having about 2.5% iron; and
sheet metal material comprising a copper alloy having about 2.5% iron.

18. A method of making an infiltrated ferrous metal compact weighing less than 5 ounces, the method comprising the acts of:

providing a ferrous metal powder;

forming the ferrous metal powder into a porous ferrous metal product having a contact surface and weighing less than 5 ounces;

providing a metal wire infiltrant pre-form comprising copper and about 2.5% iron by weight, the metal wire infiltrant pre-form weighing less than about ½ ounce, the metal wire infiltrant pre-form being shaped to be supportable on the porous ferrous metal powder contact surface;

placing the infiltrant pre-form on the porous ferrous metal powder product contact surface; and

heating the combination of the infiltrant pre-form and the porous ferrous metal product so that at least some of the metal in the infiltrant pre-form infiltrates into the porous ferrous metal product to form the infiltrated ferrous metal product.

FIG. 1
PRIOR ART

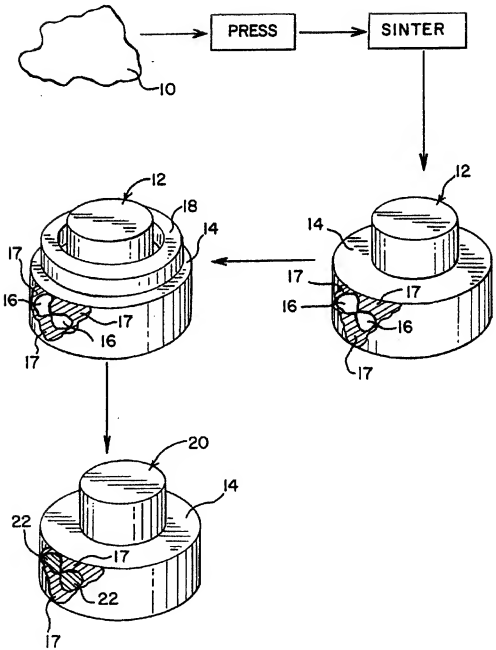


FIG. 2

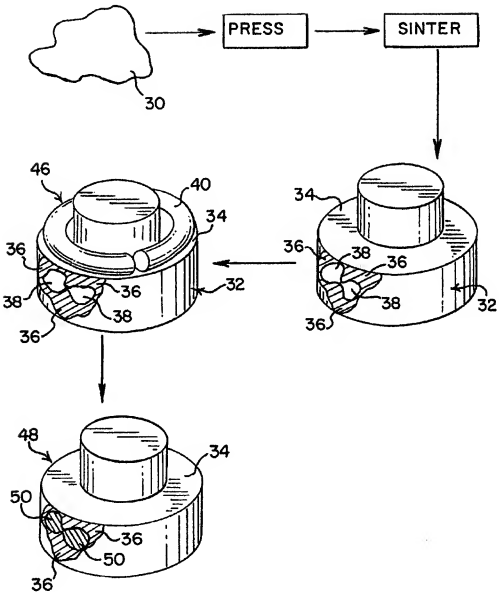

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FIG.3

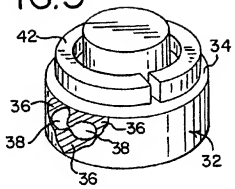

FIG.4